Using climate information to make (intelligent) decisions in the energy sector: the ENEA experience

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“Around 30% of electricity in Europe is produced from renewables. In 15 years, this will go up to about 50%. A paradigm shift is well underway in electricity!”
- Bente Hagem (ENTSO-E)

Energy & Meteorology

- Link between Energy and Meteorology is strengthening for several reasons:

1. Diffusion of Renewable Energies
2. Widespread use of air conditioning
3. Necessity of improving efficiency/reliability of power networks (electric utilities)

INFORMATION IS

POWER

Energy & Weather/Climate

- Which energy sectors are affected by weather and climate?

Climate & TSO

Transmission System Operators (TSOs) are responsible for:

- ensuring the long-term ability of the system to meet demands for electricity
- contributing to security of supply
- managing electricity flows on the system

EUR-Lex - Internal market in electricity - 2009/72/EC

	Weather Information	Climate Information
Electricity Demand	Analysis of past events	Demand forecasting from 1 to 3 months (seasonal)
Renewable Energy Production	Short-term forecasting	Seasonal Forecasting

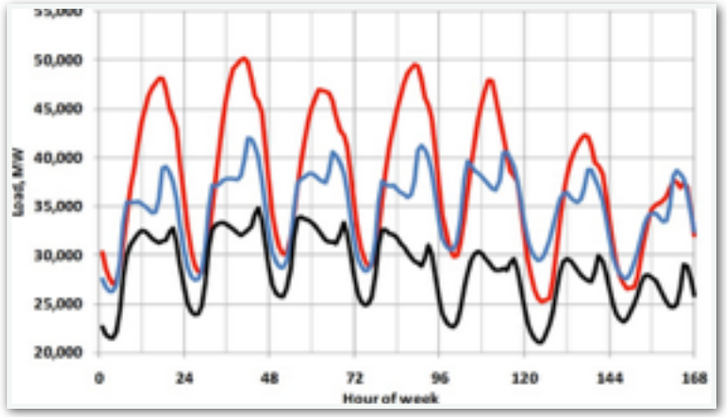
Terna

entsoe
Reliable Sustainable Connected

Climate Influence

TSOs are responsible for:

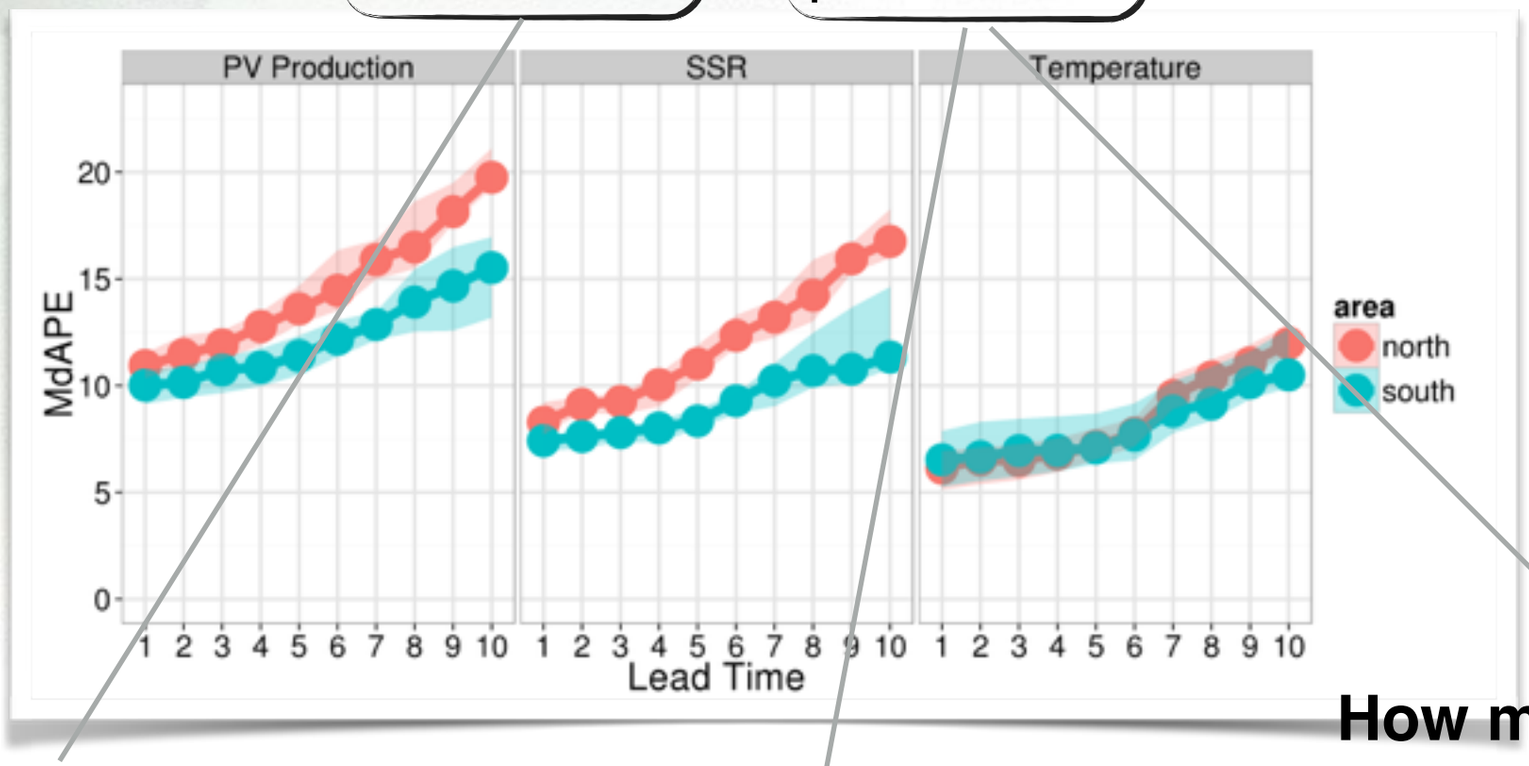
- ensuring the long-term ability of the system to meet demands for electricity
- contributing to security of supply managing electricity flows on the system



Temperature Wind Solar Radiation

Supply: solar power

- Photovoltaics: estimate & predict



How much are we producing now?

How much we will produce tomorrow?

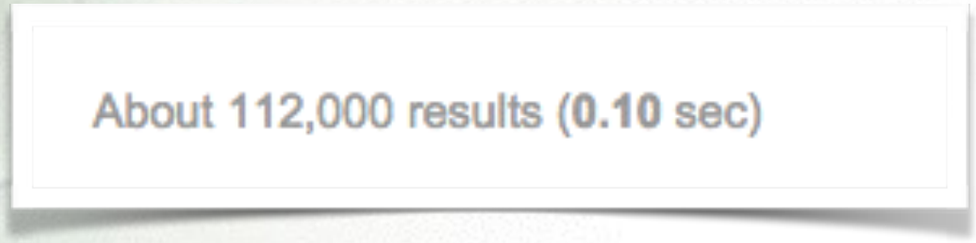
How much we will produce next summer?

M. De Felice, M. Petitta, and P. M. Ruti, “Short-term predictability of photovoltaic production over Italy,” Renewable Energy, vol. 80, pp. 197-204, 2015.

SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

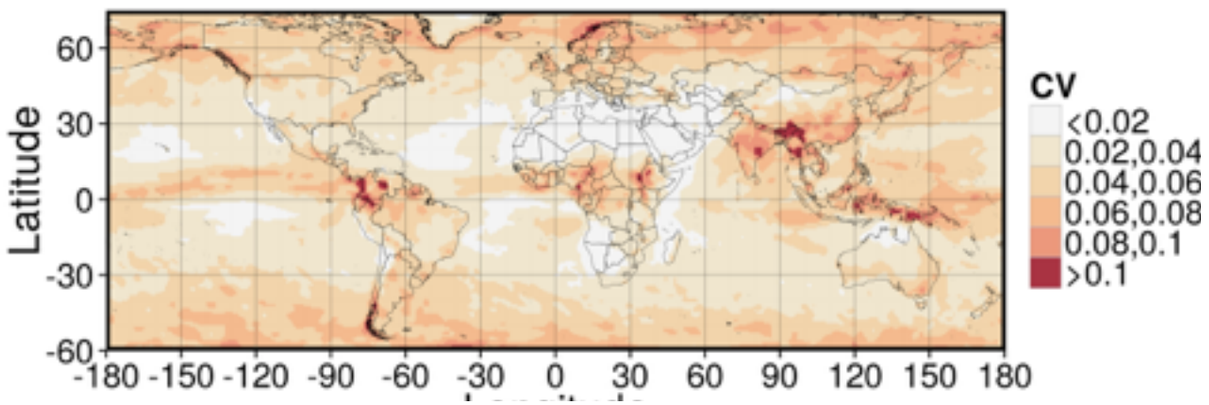
Going seasonal…

- Short-term solar forecasting/prediction

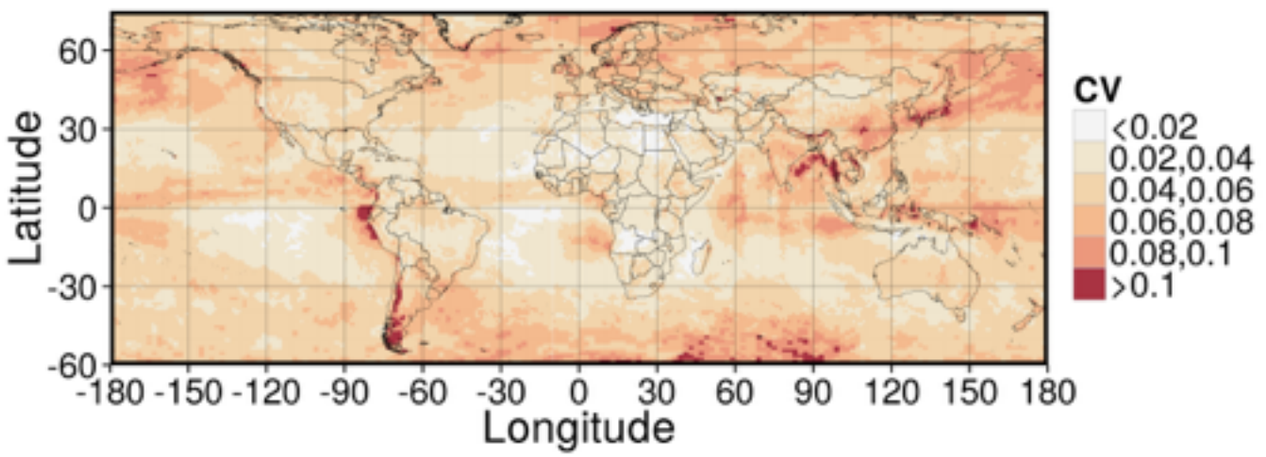


- Seasonal solar forecasting/ prediction

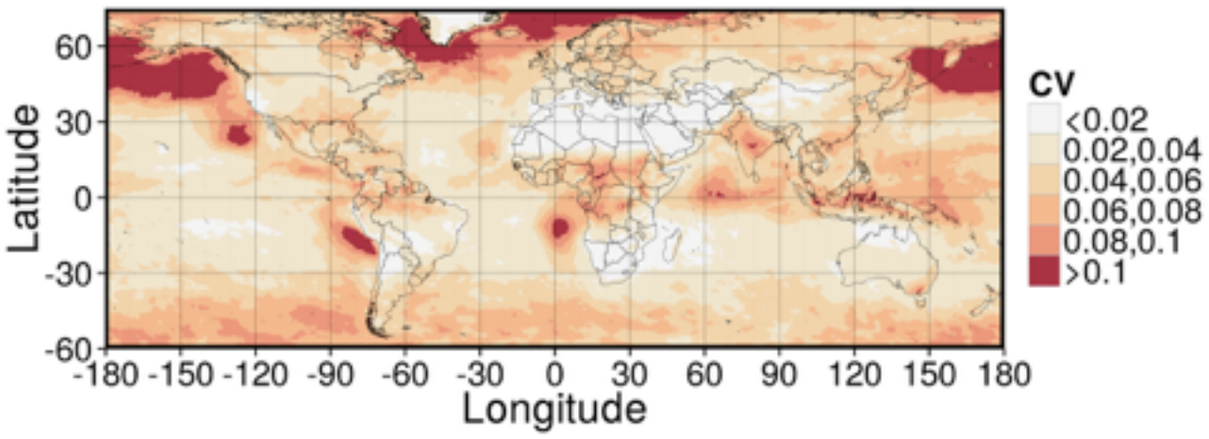
Inter-annual solar variation



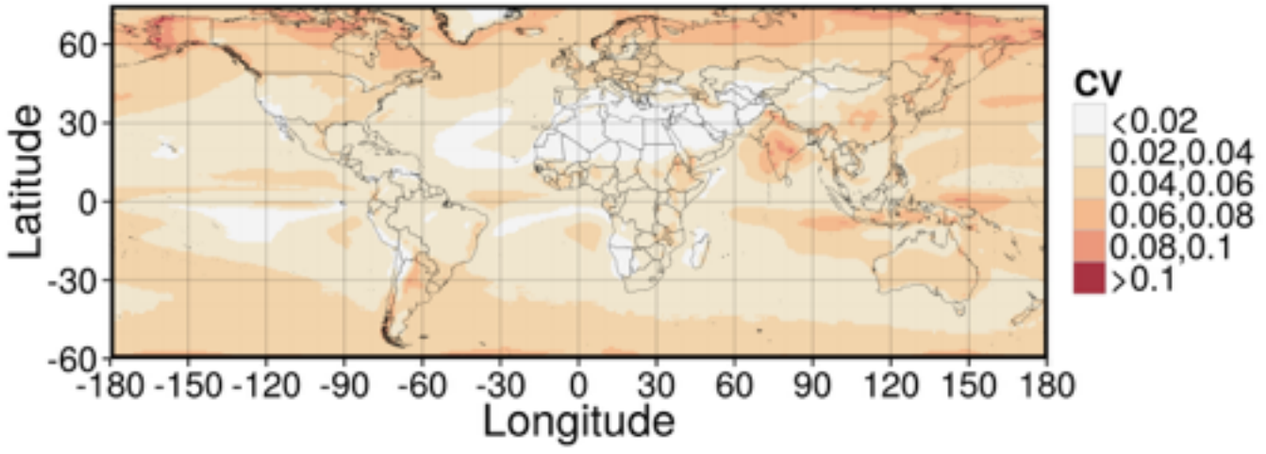
ERA-INTERIM



SRB



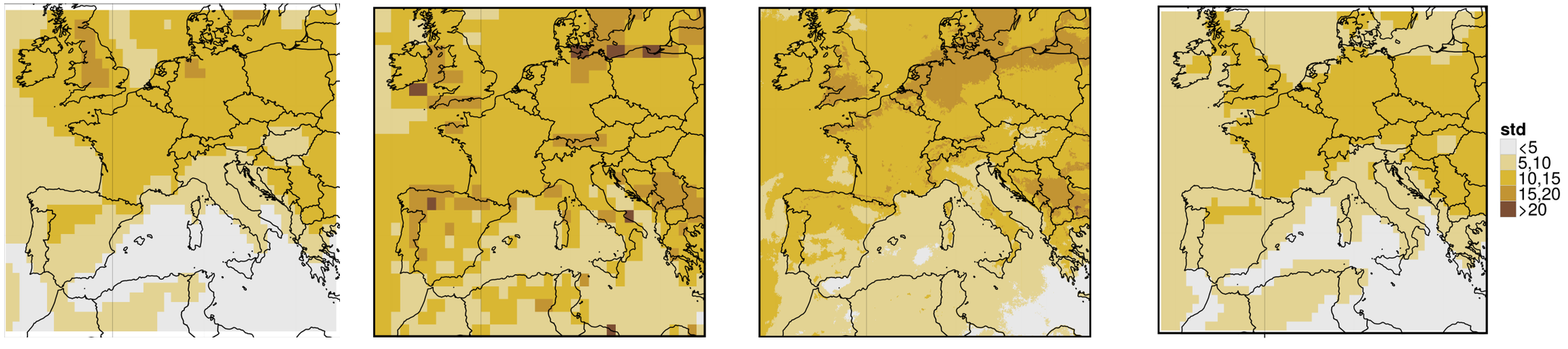
MERRA



System4 - 51 members

SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Inter-annual solar variation

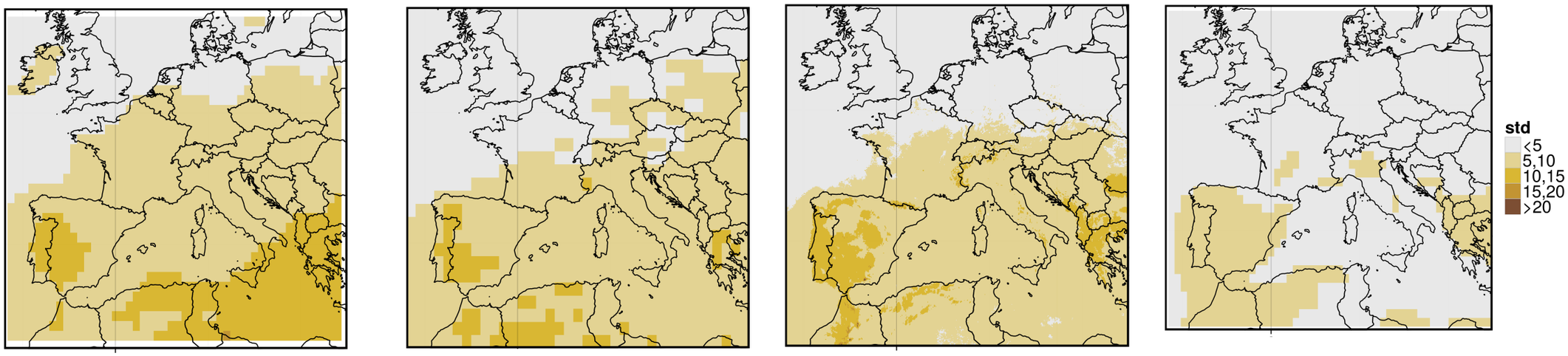


ERA-INTERIM

NASA/GEWEX SRB

CM SAF SARAH

SYS4-51



SPECS

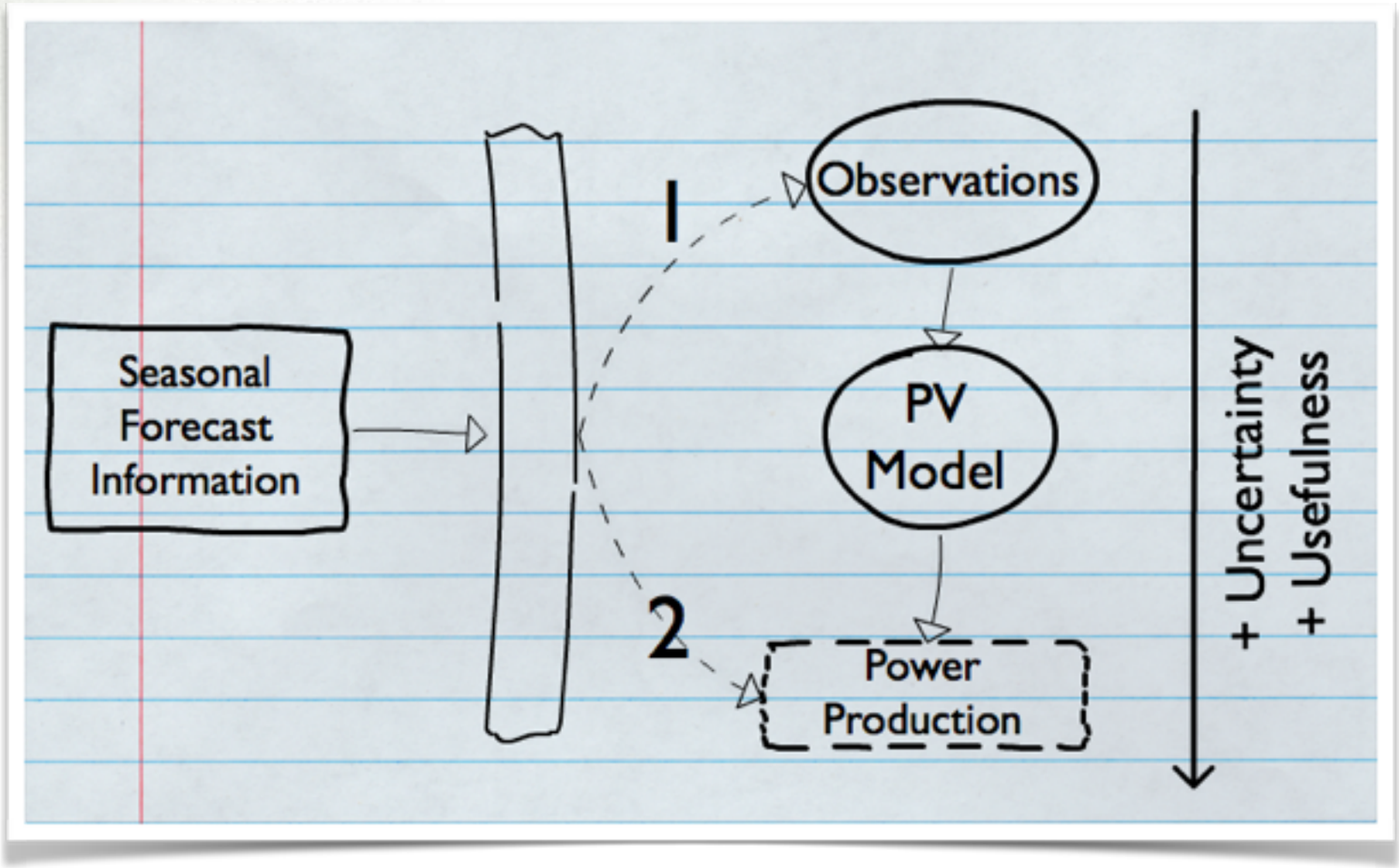
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

And now?

The target is the electricity production…

1. Use of large-scale climate information to estimate the predictors of PV power (solar radiation, temperature)

2. Use of large-scale climate information to predict electricity production



Next 12 months

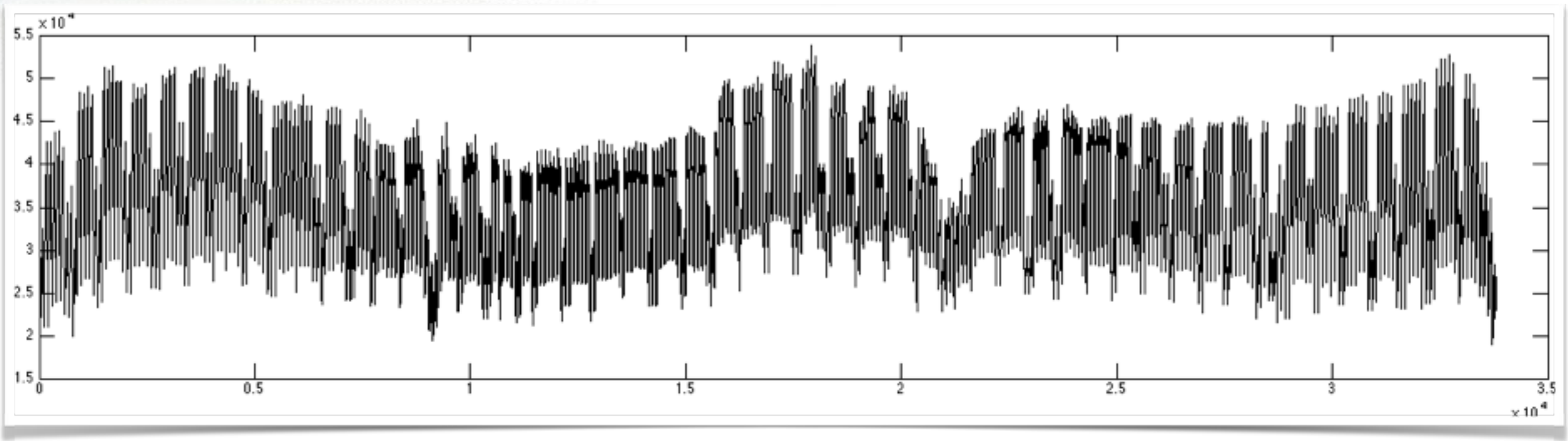
- Checking actual probabilistic skills in predicting solar radiation

- Exploiting large-scale information using PCA/EOF regression

- Creation of artificial datasets of PV production

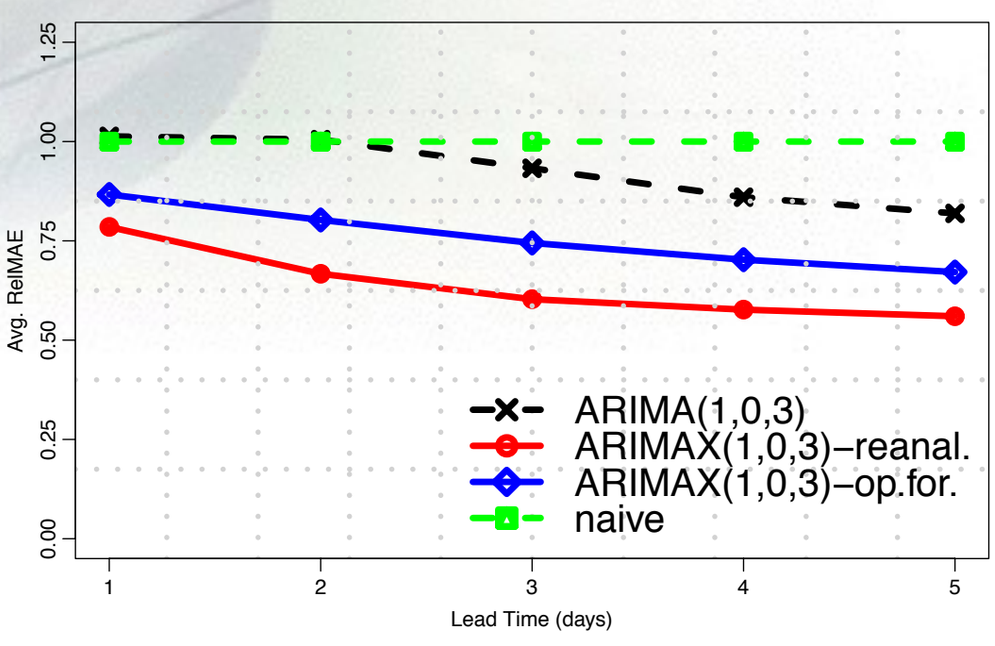
Electricity Demand

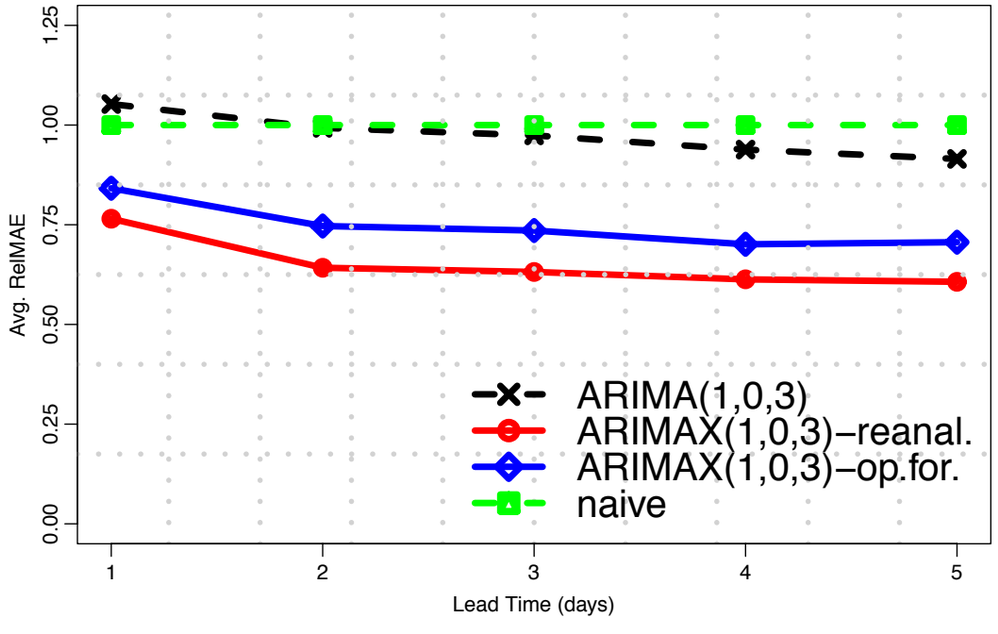
- Electricity demand sensitive to weather conditions
- Currently only climatological data are used for time-scales >14 days
- Demand affected by “human activities” (calendar effects) and economic trends



Electricity Demand

- Electricity Demand…
  - …and how it is affected by temperature
  - …and its predictability at short-time scales

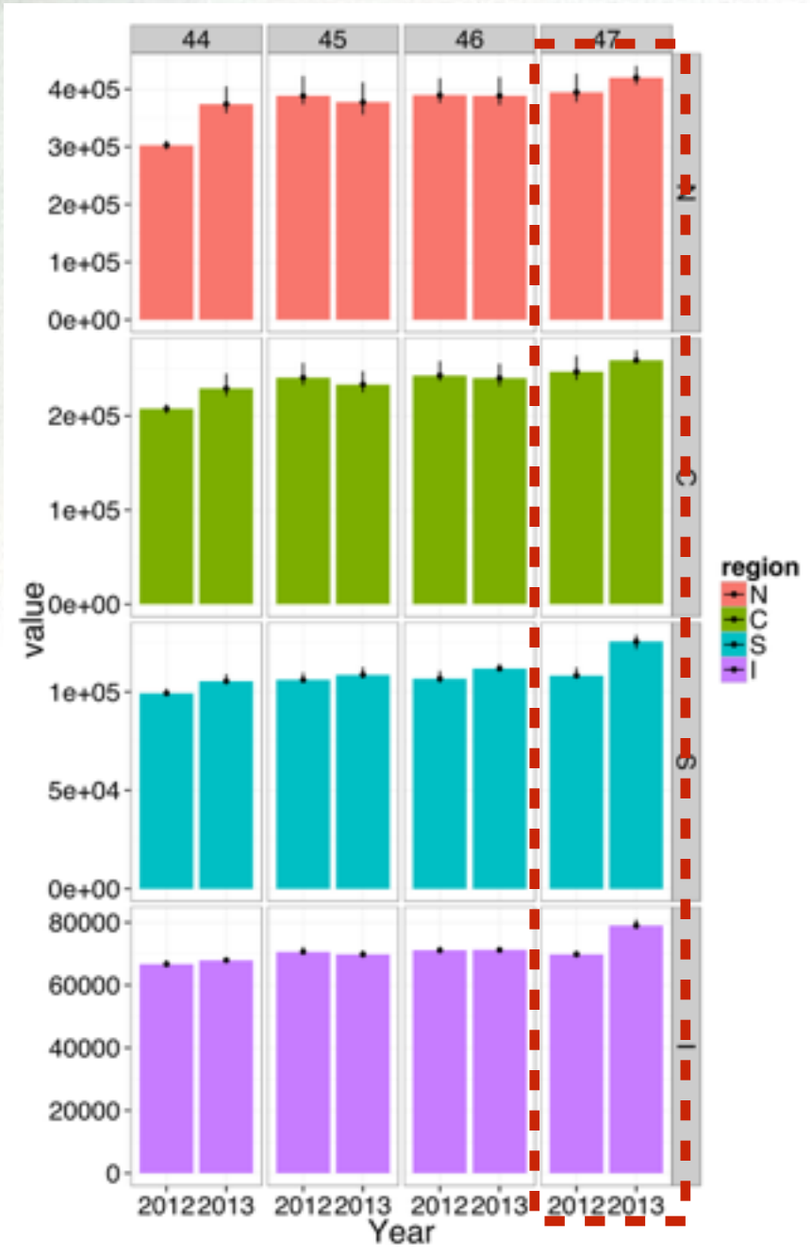


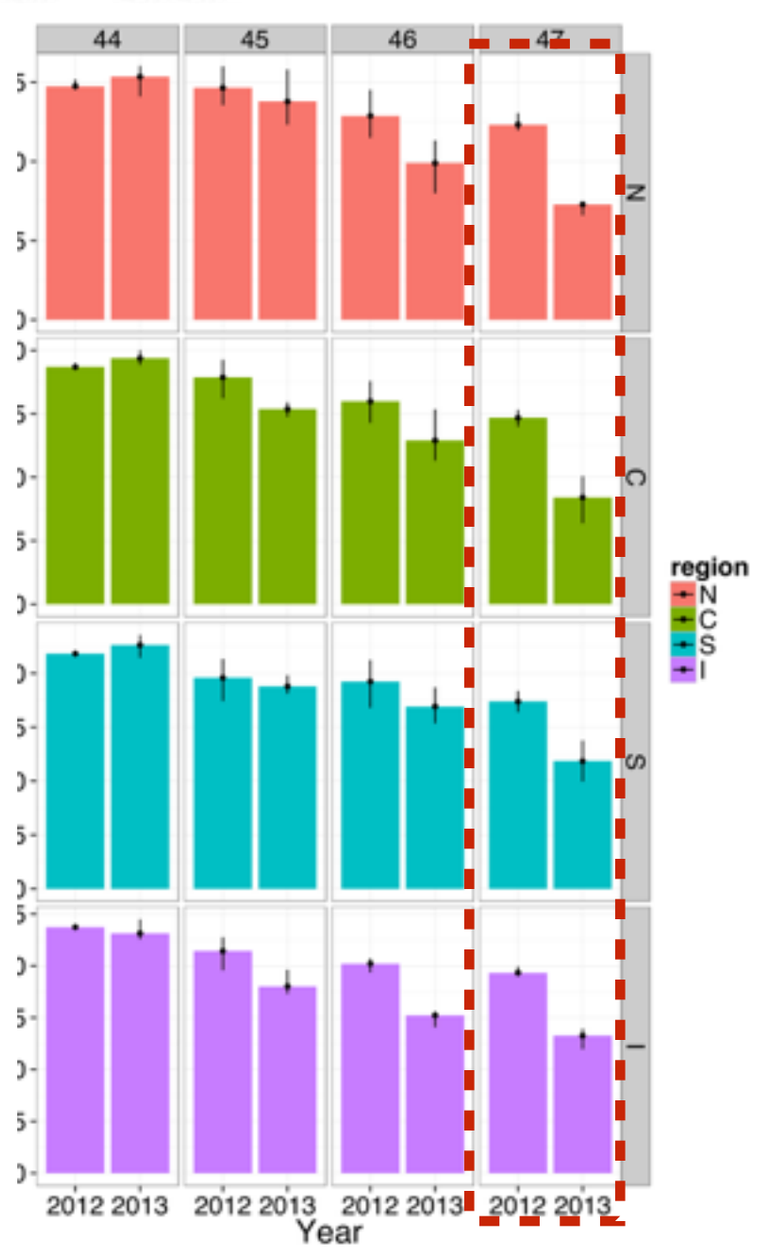


M. De Felice, A. Alessandri, and P. M. Ruti, “Electricity Demand Forecasting over Italy: Potential Benefits using Numerical Weather Prediction models,” Electric Power Systems Research, vol. 104, pp. 71-79, 2013.

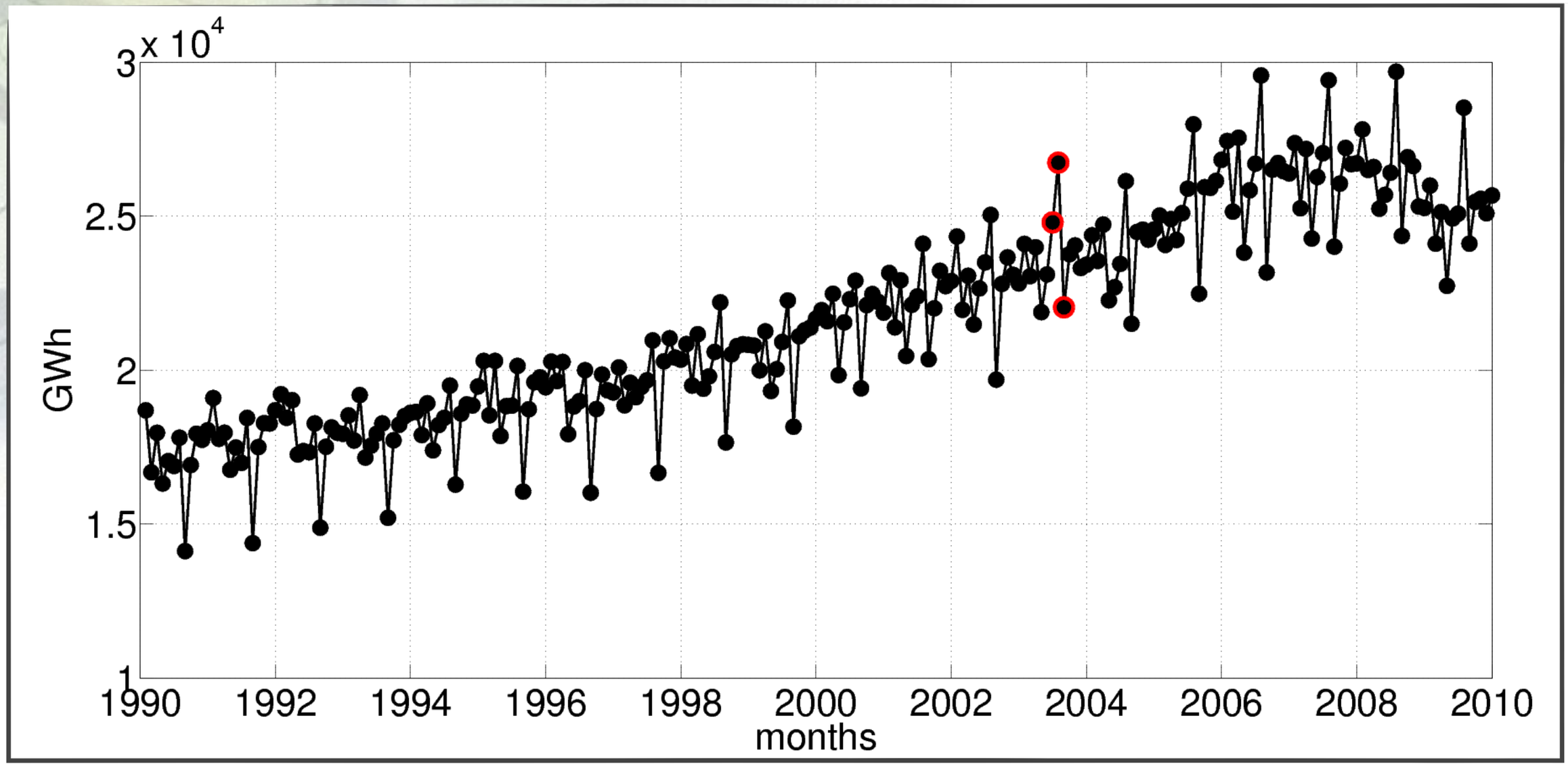
A question…

What has happened?



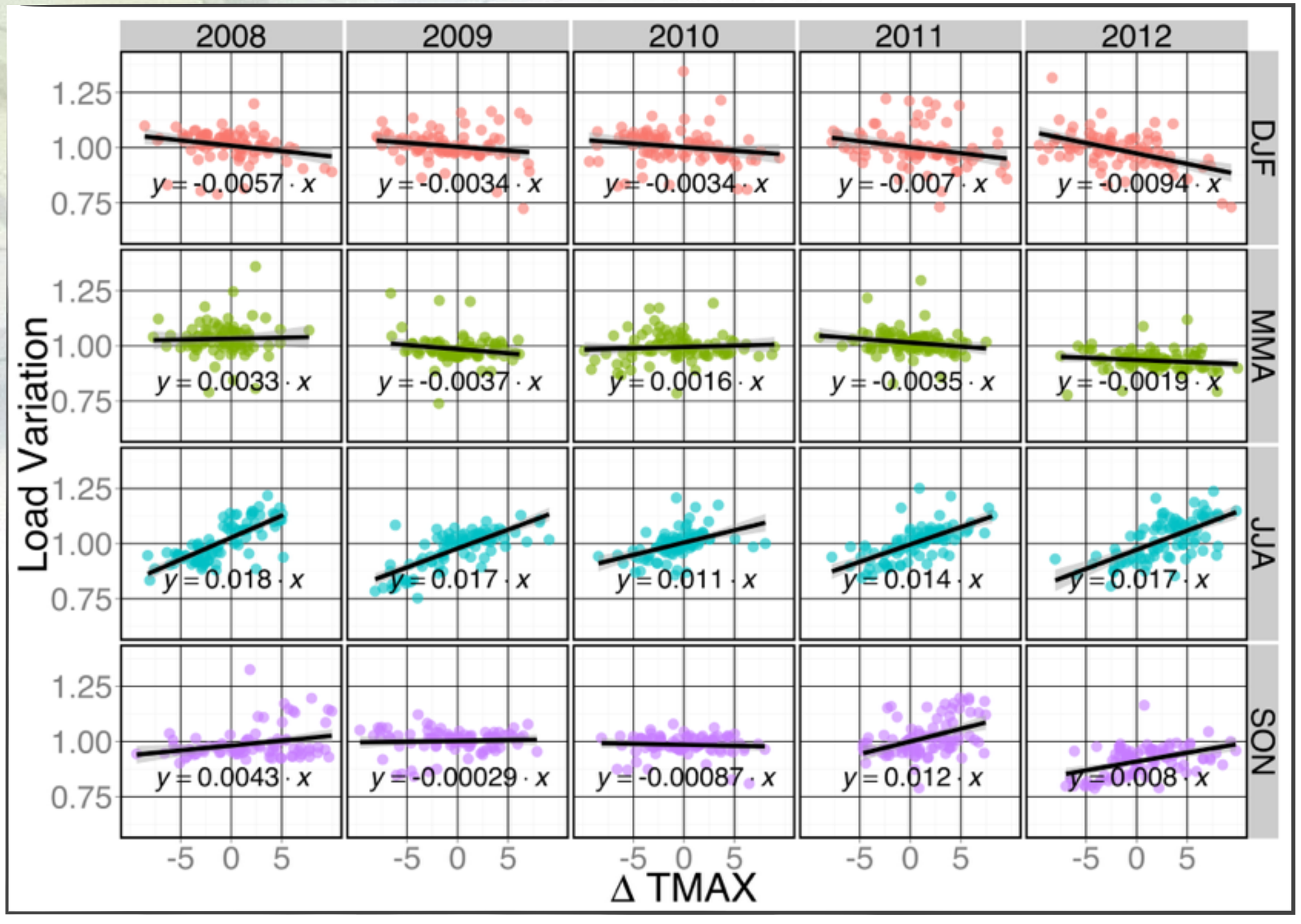


Electricity Demand…



https://mdefelice.shinyapps.io/EUPORIAS-ECM15

Observe


2008
2009
2010
2011
2012
DJF
MMA
JJA
SON
Load Variation
Δ TMAX
1.25
1.00
0.75
-5
0
5
y = -0.0057 · x
y = -0.0034 · x
y = -0.0034 · x
y = -0.007 · x
y = -0.0094 · x
y = 0.0033 · x
y = -0.0037 · x
y = 0.0016 · x
y = -0.0035 · x
y = -0.0019 · x
y = 0.018 · x
y = 0.017 · x
y = 0.011 · x
y = 0.014 · x
y = 0.017 · x
y = 0.0043 · x
y = -0.00029 · x
y = -0.00087 · x
y = 0.012 · x
y = 0.008 · x

What about the next months?

Energy Sector Vulnerability

- E.g. During European 2003 heat-wave France reduced electricity export in August of 50% (EDF)

> […] a summer average decrease in capacity of power plants of 6.3–19% in Europe and 4.4–16% in the United States depending on cooling system type and climate scenario for 2031–2060. In addition, probabilities of extreme (>90%) reductions in thermoelectric power production will on average increase by a factor of three.
>
> *(van Vliet et al., Vulnerability of US and European electricity supply to climate change, Nature Climate Change 2(9), 2012)*


PROBLEMS
AHEAD
NEXT
14 MILES

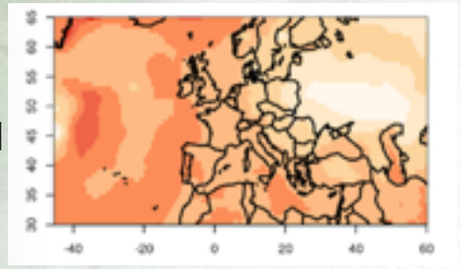
Going seasonal

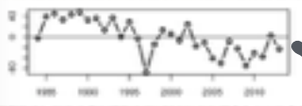
- What will be the probability of having the demand above/below the normal?
- Use of “statistical downscaling” of seasonal forecasts
- Interesting result: significant skill (BSS > 0.3) on some Italian regions with one-month of lead time

De Felice M., Alessandri A., and F. Catalano, “Seasonal climate forecasts for medium-term electricity demand forecasting,” Applied Energy, vol. 137, pp. 435-444, 2015

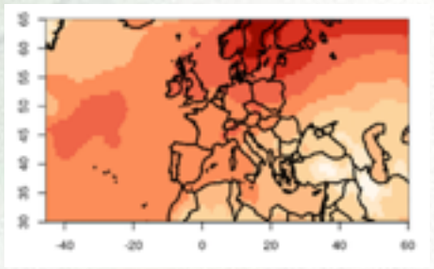
Seasonal Forecast

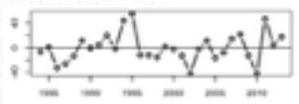
VAR1 MEM1 PC1



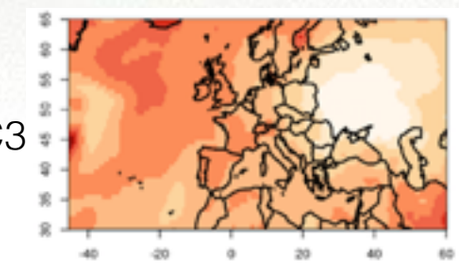


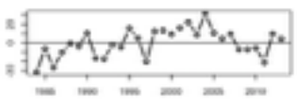
VAR1 MEM1 PC2





VAR1 MEM1 PC3

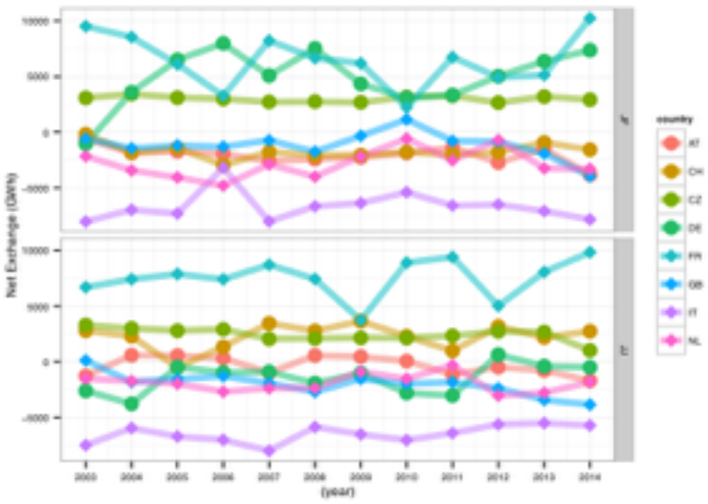




•
•
•

VAR_X MEM_Y PC_Z

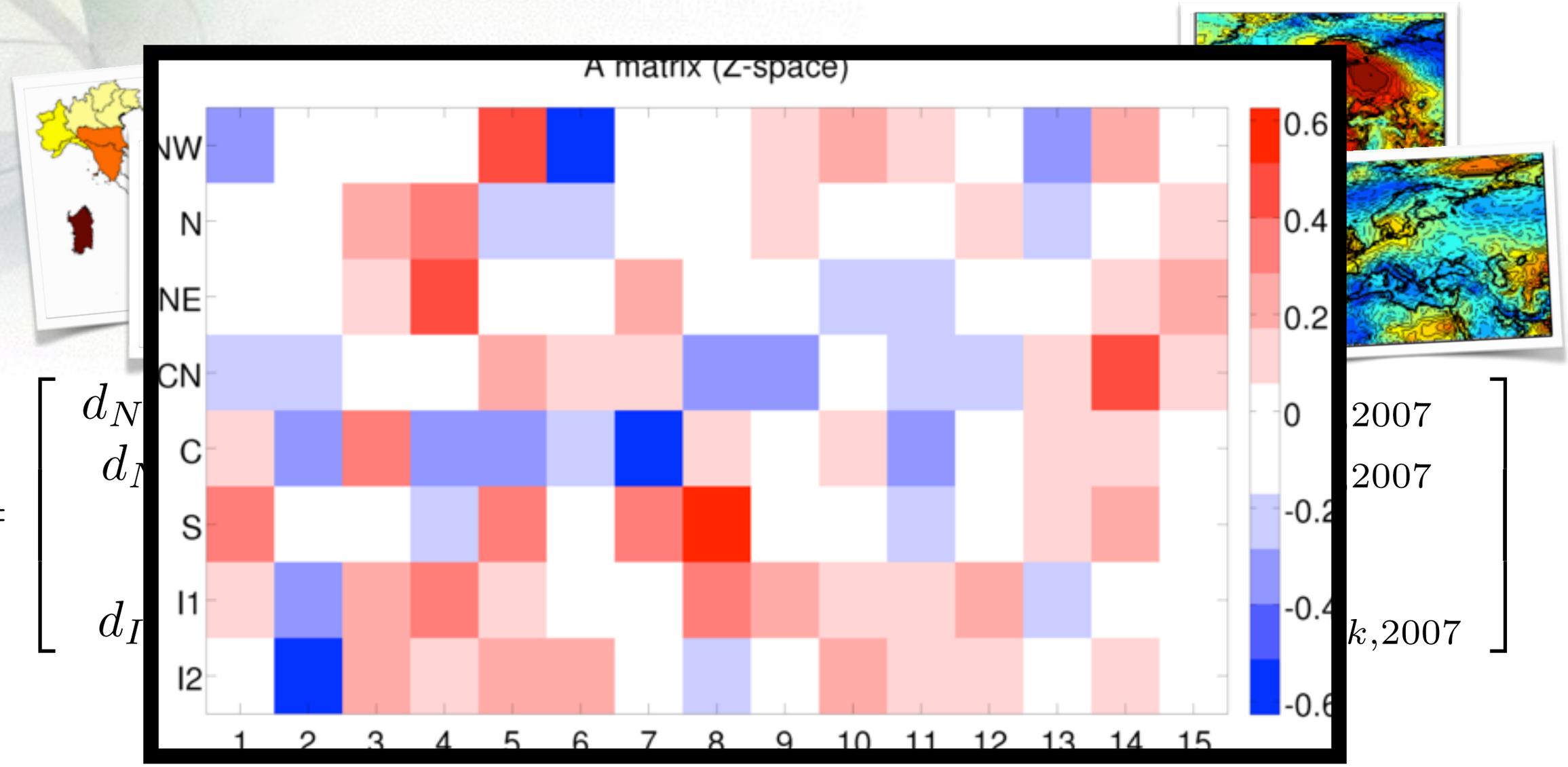
ML Method



Target (predictand)

A possible approach

- Find the relationship between seasonal forecast patterns and observed demand



$$\mathbf{Z} = \begin{bmatrix} d_{N} \\ d_{N} \\ \\ \\ d_{I} \end{bmatrix}$$

2007

2007

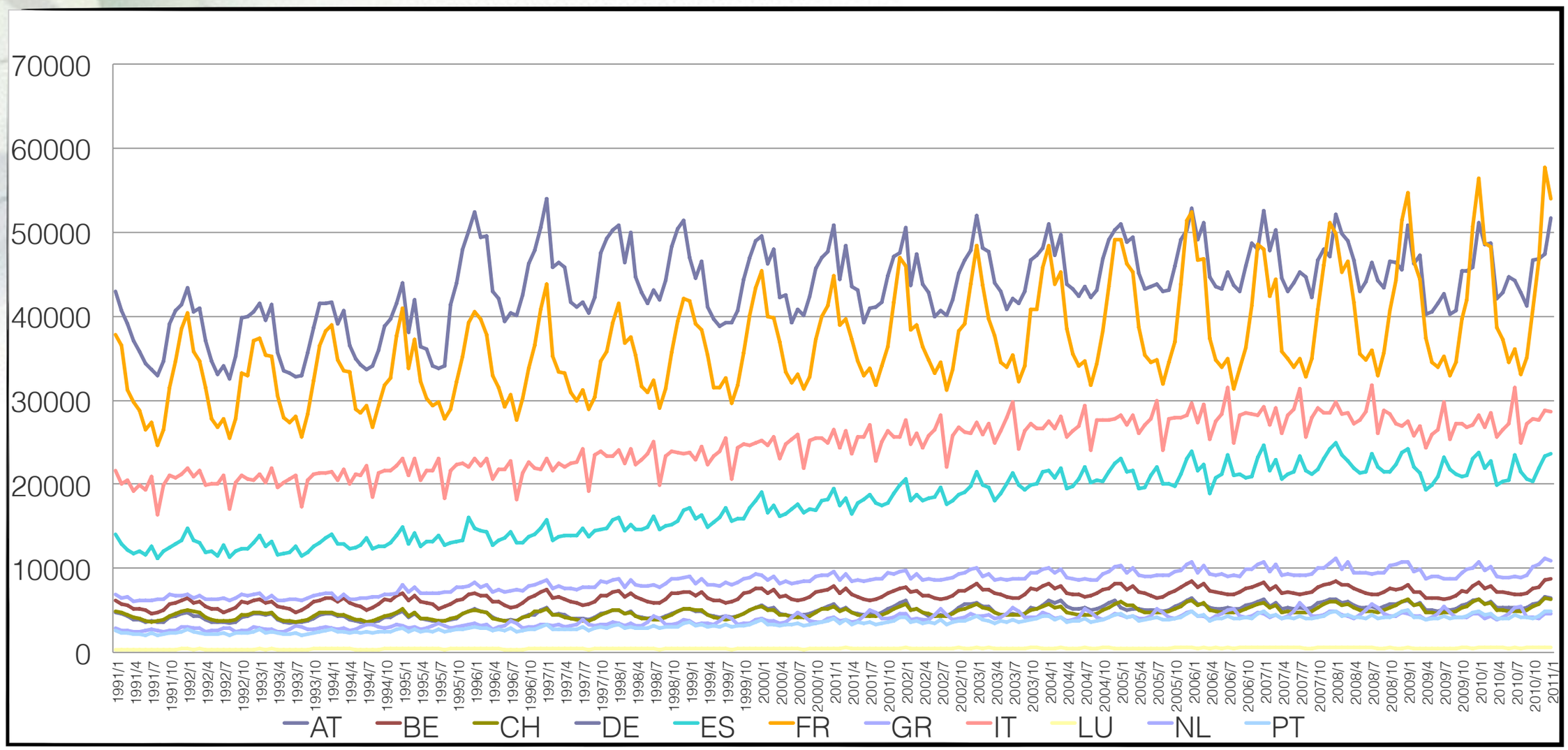
$k,2007$

A possible product

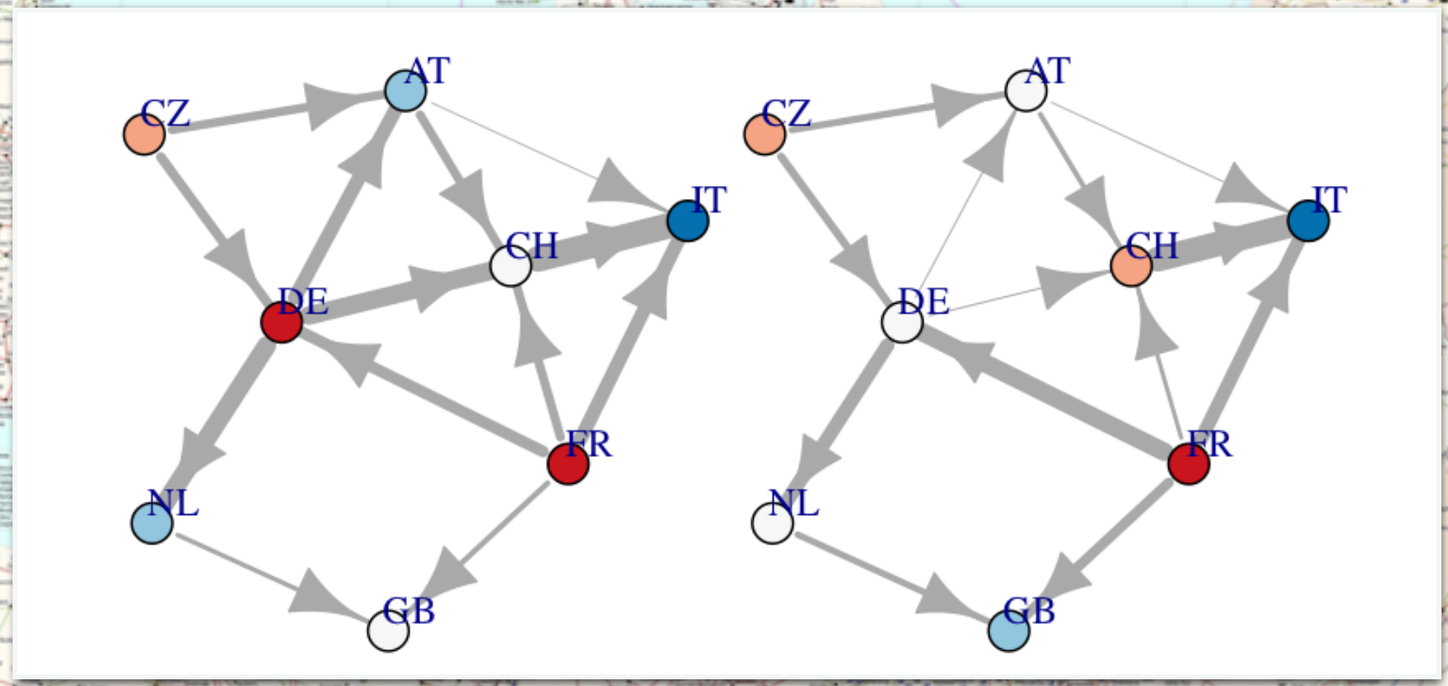
	Center (C)			South (S)		
Year	Above normal?	May	April	Above normal?	May	April
1990	Yes	37.3%	33.3%	No	31.4%	33.3%
1991	No	23.5%	20%	No	25.5%	26.7%
1992	No	43.1%	46.7%	Yes	60.8%	46.7%
1993	No	13.7%	46.7%	No	35.3%	46.7%
1994	Yes	86.3%	33.3%	No	49%	33.3%
1995	No	29.4%	53.3%	Yes	15.7%	40%
1996	No	29.4%	40%	No	25.5%	46.7%
1997	No	39.2%	26.7%	Yes	60.8%	33.3%
1998	No	31.4%	33.3%	Yes	52.9%	46.7%
1999	No	5.9%	6.7%	No	0%	6.7%
2000	No	29.4%	6.7%	No	2%	0%
2001	No	23.5%	20%	No	2%	0%
2002	Yes	52.9%	26.7%	Yes	41.2%	20%
2003	Yes	68.6%	46.7%	Yes	94.1%	46.7%
2004	No	15.7%	53.3%	No	47.1%	46.7%
2005	Yes	33.3%	26.7%	No	49%	46.7%
2006	Yes	41.2%	73.3%	No	7.8%	53.3%
2007	No	13.7%	26.7%	No	27.5%	46.7%

Next steps…

Extending to Europe (ENTSO-E)

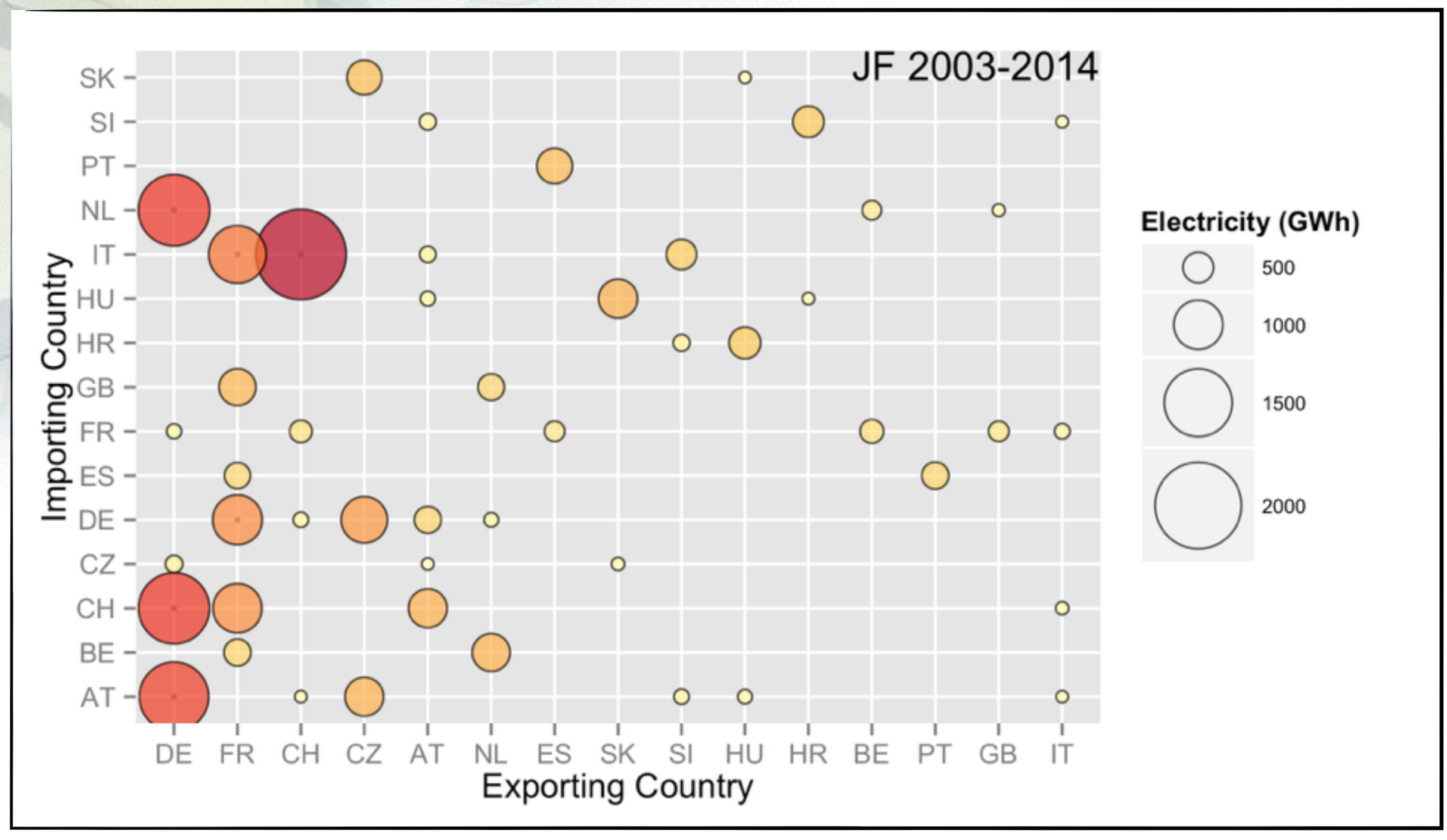


Electricity Exchange

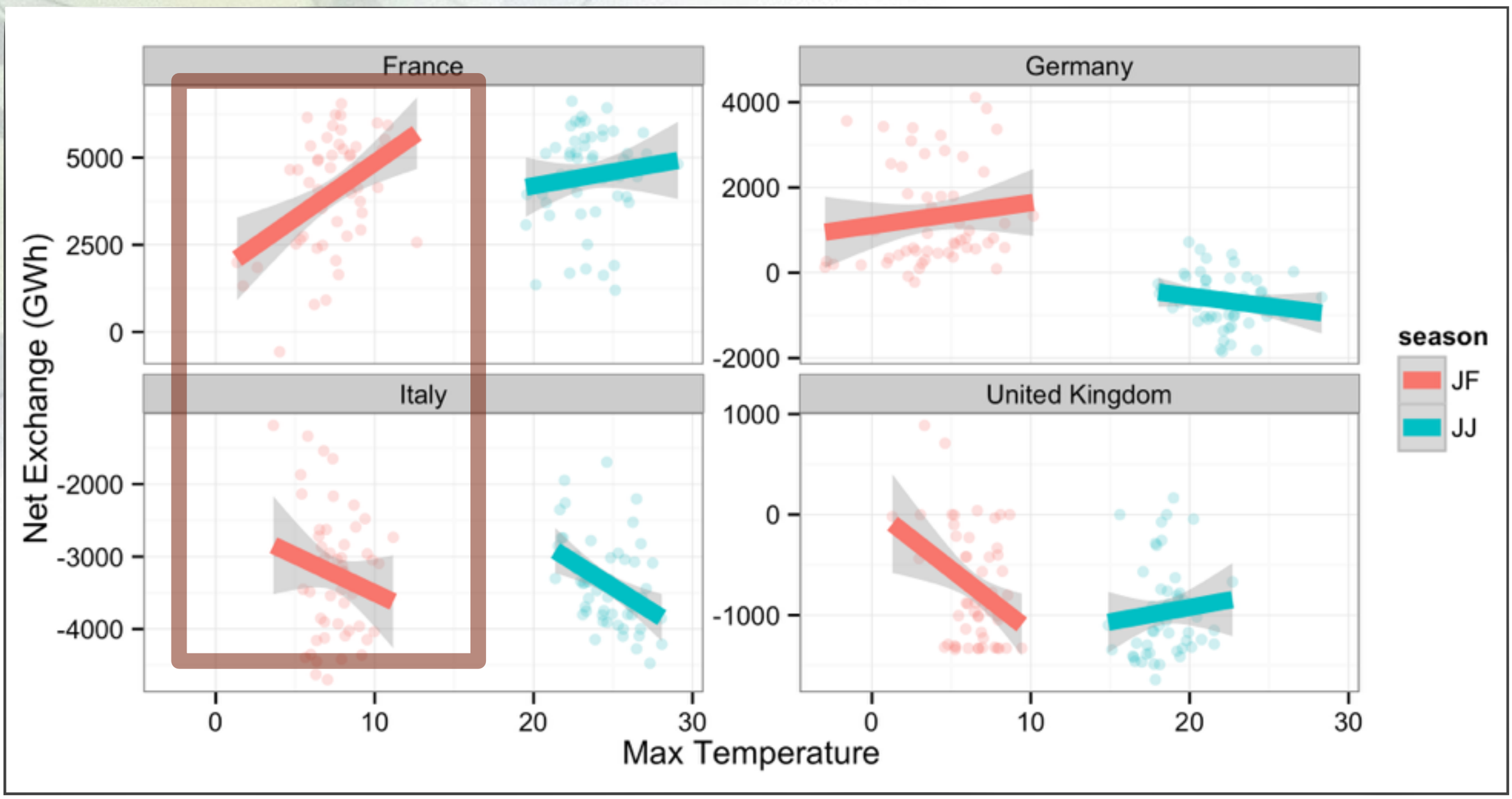


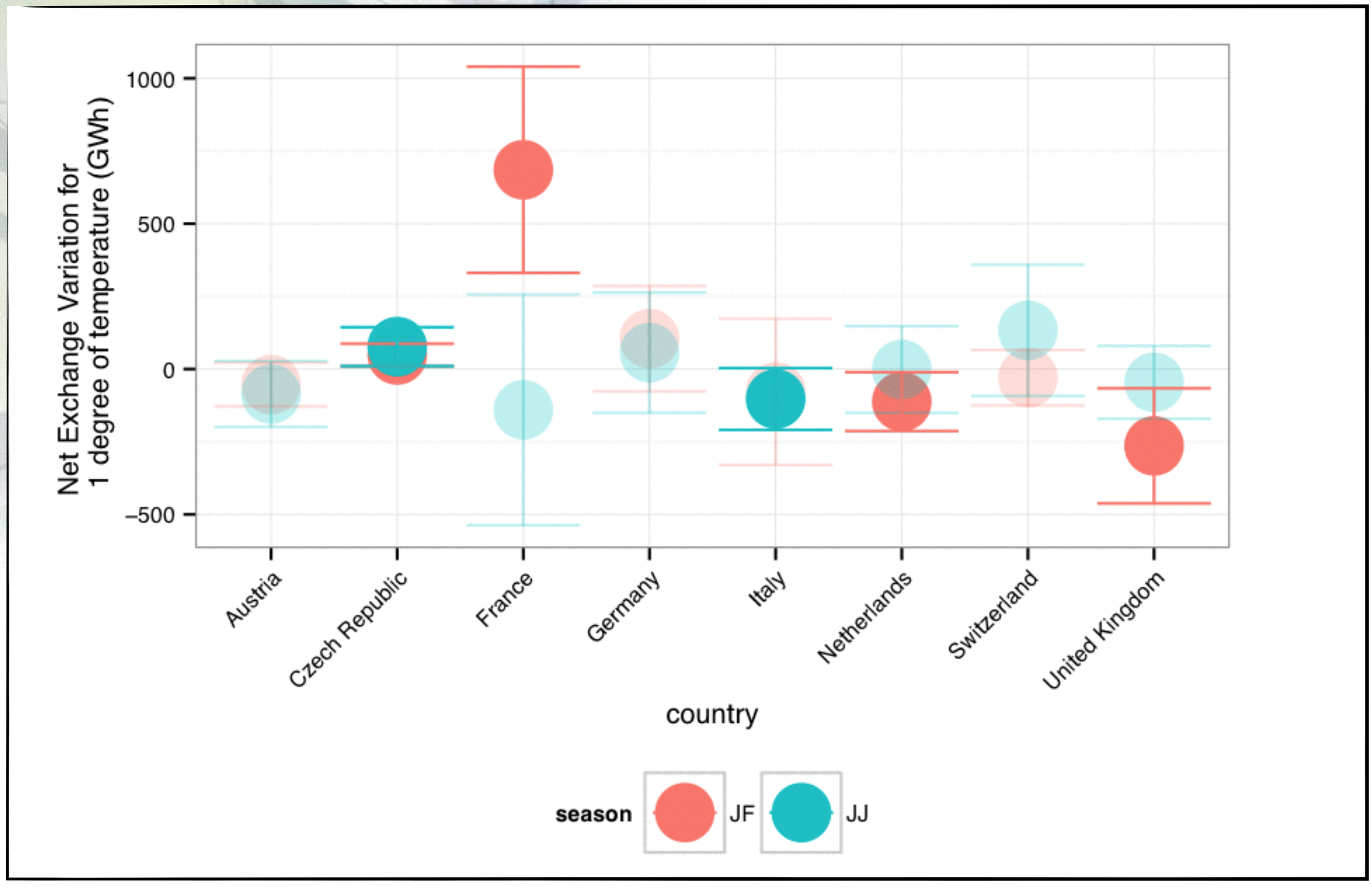
European electricity flows for Jan-Feb (left) and June-July (right) – red nodes are the main exporters and blue the main importers – Data from ENTSO-E (2003-2014)

European exchanges



Flows


France
Germany
Italy
United Kingdom
Net Exchange (GWh)
Max Temperature
5000
2500
0
-2000
-3000
-4000
4000
2000
0
-2000
1000
0
-1000
0
10
20
30
season
JF
JJ


Net Exchange Variation for 1 degree of temperature (GWh)
1000
500
0
−500
Austria
Czech Republic
France
Germany
Italy
Netherlands
Switzerland
United Kingdom
country
season
JF
JJ